



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION 5
9311 GROH ROAD
GROSSE ILE, MI 48138

MEMORANDUM

SUBJECT: Risk Assessment for the Pilsen Railroad and Alley Area Adjacent to the H. Kramer Smelter

FROM: Keith Fusinski, PhD Toxicologist US EPA
Superfund Division, Remedial Response Branch #1, Remedial Response Section #1

TO: Ramon Mendoza, OSC
Superfund Division, Emergency Response Branch #2, Remedial Response Section #3

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BACKGROUND

H. Kramer and Company is a brass smelting company located in the Pilsen neighborhood of Chicago, Illinois, United States. The smelter has been melting scrap metal into brass and bronze ingots since the 1920s. In the March 2005, Pilsen residents began sampling the soil and found elevated levels of lead around the H. Kramer facility. Sampling performed by H. Kramer in June 2005 found lead on the site at levels ranging from 1,250 to 65,000 parts per million (ppm), and from 120 to 2,500 ppm off site. The H. Kramer property has since been remediated. However, areas beyond the property boundaries have not. US EPA recommends residential soil lead levels not to exceed 400 ppm and soils on commercial or industrial properties not to exceed 800 ppm.

The H. Kramer property is located within a quarter mile of residential dwellings and area schools. There is an abandoned railroad spur and an alley which are adjacent to the property. Local children walk through the rail spur and alley to get to and from school and during recreational times spent outdoors. Sampling performed by US EPA demonstrated that the rail spur, the alley and residential neighborhoods have lead contamination levels well above US EPA residential and commercial removal action levels. The alley also has levels of antimony, copper and arsenic above US EPA residential removal actions levels (RMLs). The rail spur has surface levels of copper and zinc above RMLs.

STATEMENT OF THE ISSUES

OSC Mendoza requested a review of the current and potential future human health risks to area residents from exposure to contamination located at the rail spur and the alley adjacent to the H. Kramer Facility.

RISK ASSESSMENT FRAMEWORK

There are two distinct locations of concern for this assessment; the abandoned rail spur and the alley. It is safe to assume that exposure to the alley and rail spur occur by workers and residents walking through them and not spending prolonged periods of time in one spot. This report will look on at exposure to the residents in these areas since they would spend a longer amount of time in the area. It is assumed that residents will be exposed to the entire alley or rail spur and not just individual areas. A 95% upper confidence limit (UCL) will be determined for each metal at each depth analyzed during the 2012 and 2013 sampling events at these locations. The UCL is the value that when calculated for a random data set equals or exceeds the true mean 95% of the time. The 95% UCL for each chemical of interest will be compared to US EPA Residential RMLs to determine if the chemical will be carried forward in the risk assessment. The alley and the rail spurs will be treated as separate exposure points for the risk assessment. The exposure areas will be discussed separately below.

Since the exposure areas are within a quarter mile of schools and residential neighborhoods, risks for metals, not including lead, will be evaluated using standard US EPA residential risk assessment equations as described in the Risk Assessment Guidance for Superfund (RAGS) documents. It will be assumed that access to soils of the exposure areas will only be for 9 months out of the year since soils are frozen and/or snow covered during the winter months. Inhalation, ingestion, and dermal exposure will all be evaluated. Due to the nature and location of the exposure areas, it will be assumed that 50% of the area resident's daily intake of incidental soil ingestion and dermal contact from these areas. Due to windblown distribution of the contaminants in the area, it will be assumed that 100% of inhalation risks for area residents come from the exposure areas. Risk will be determined for children (age 0-6 years old), adolescents (7-19 years old) and adults (greater than 19 years old). Based upon the RAGS guidance, it will be assumed that the body weight of a child is 15 kg and an adult is 70kg. There is no default value for body weight for an adolescent in the RAGS guidance. However, an average body weight can be calculated for an adolescent from information in the Exposure Factor Handbook (EHF). Based upon information tables, the average body weight for an adolescent is 48kg.

The US EPA regional screening level table user's guide recommends that trivalent and hexavalent chromium are analyzed for individually. However, only total chromium was analyzed for at this site. It is well known that hexavalent chromium is more toxic than trivalent chromium. In order to not over look the potential effects of hexavalent chromium exposure, the recommended 6:1 ratio will be used on the total chromium concentration at the site. For this assessment, the total chromium concentration will be divided by 7 to determine the potential concentration of hexavalent chromium. The potential concentration of hexavalent chromium will be subtracted from the total chromium concentration to determine the potential concentration of trivalent chromium on the soils.

Lead exposure risk will be based upon fine lead data. Fine lead is smaller particles of lead which can be more easily disturbed and become airborne which results in a higher incidence of exposure to the residents. Risk from lead exposure is calculated using exposure models which predict blood lead levels in children or unborn children of pregnant mothers, and not the default calculations as described above. As such, in accordance to the US EPA Superfund Lead-Contaminated Residential Sites Handbook, average concentrations of the recent lead data will be used to determine risks from lead exposure. The average lead concentration from each of the exposure areas will be evaluated in both the Integrated Exposure Uptake Biokinetic (IEUBK) model and the Adult Lead Model (ALM). The IEUBK model is used to predict blood lead levels in children 0 to 6 years old. ALM model is used to predict not only the blood levels of adults but also the probability of the blood lead levels in an unborn child of pregnant women exceeding the recommended blood lead of 10 µg/dl in children. It is important to note that CDC has recently recommended that the blood lead level in children not exceed 5 µg/dl, US EPA is still evaluating that recommendation. Both will be evaluated in this report. The ALM will also be used to assess the predicted blood lead level of school aged children above the age of 6 years old as defined in section 4.2.2 of the US EPA Intermittent Exposure Guidance.

Identifying Chemicals of Potential Concern

ALLEY

Alley 0-6 inches all non-lead metals

Table 1 below shows the minimum and maximum concentrations of metals detected from twelve composite and one grab sample collected on December 19th, 2013 for the top 6 inches of soil in the alley. Table one also shows the 95% UCL of the data set as compared to the Removal Management Level (RML). There are two areas in the alley where concentrations of antimony exceed the RMLs, and the 95% UCL for antimony exceed the RML. There are also five areas where arsenic concentrations are above the RML. However the 95% UCL for arsenic is below the RML. There are also 6 areas where the calculated concentration of hexavalent chromium could potentially exceed the RML. The 95% UCL for chromium in the top 6 inches of soil in the alley is above the RML. Based upon the above information, both antimony and chromium will be taken forward into the risk assessment for the alley.

	Units	RML	Alley 0-6 inches		
			Min	Max	95% UCL
Antimony	mg/kg	94	13	290	149
Cadmium	mg/kg	210	0.96	42	22
Chromium	mg/kg	--	7	3,400	2,239
Chromium(III)	mg/kg	350,000	6	2,914	1,919
Chromium(VI)	mg/kg	29	1	486	320
Copper	mg/kg	9,400	230	8,400	4,370
Tin	mg/kg	140,000	14	1,600	791
Zinc	mg/kg	70,000	180	14,000	9423
Mercury	mg/kg	30	0.04	3.6	1.6
Arsenic	mg/kg	39	1.9	51	33
Barium	mg/kg	46,000	32	1,600	718
Selenium	mg/kg	1,200	1.9	4.6	3.3
Silver	mg/kg	1,200	1.9	41	20

Table 1. Non- lead metal concentration in the alley at 0 to 6 inches below the ground surface.

Alley 0-6 inches lead

The average fine lead concentration in the alley at 0-6 inches is 2,591 mg/kg (Table 2). This concentration is greater than 6 times higher than the removal management level for lead and will be carried forward in the risk assessment.

	Units	RML	Alley 0-6 inches
			Average Concentration
Lead	mg/kg	400	2,591

Table 2. Average lead concentrations in the alley at 0-6 inches bgs.

Alley 6-12 inches bgs all non-lead metals

Table 3 shows the minimum, maximum, and 95% UCL concentrations of metals compared to RMLs from 5 composite samples collected on December 19th, 2013 from 6 to 12 inches below the ground surface (bgs). There are two areas in the alley where concentrations of antimony exceed the RMLs. The 95% UCL for antimony also exceeds the RML. Concentrations of copper exceed the RMLs at two locations in the alley and the 95% UCL also exceeds the RMLs at 6-12 inches bgs in the alley. There are three areas where arsenic concentrations are above the RML at 6-12 inches bgs in the alley. The 95% UCL for arsenic is above the RML at 6-12 inches bgs in the alley. There is one RML exceedance of the calculated hexavalent chromium concentration at 6-12 inches bgs in the alley. The suggested 95% UCL for hexavalent chromium is above the RML, but it is also above the maximum concentration of hexavalent chromium. Therefore, the maximum concentration of hexavalent chromium would be carried forward in the risk

assessment if needed. However, it is import to note that local residents would not be normally exposed to concentrations of metals below 6 inches in the alley so these concentrations will not be discussed in the risk assessment. However, the concentrations at 6-12 inches bgs may become an issue if any future excavation takes place in the alley below 6 inches.

	Units	RML	Alley 6-12 inches		
			Min	Max	95% UCL
Antimony	mg/kg	94	20	440	409
Cadmium	mg/kg	210	13	40	37
Chromium	mg/kg	--	35	510	1,167
Chromium(III)	mg/kg	350,000	30	437	999*
Chromium(VI)	mg/kg	29	5	73	168*
Copper	mg/kg	9,400	660	33,000	26,091
Tin	mg/kg	140,000	88	2,200	1,954
Zinc	mg/kg	70,000	3,000	14,000	10,980
Mercury	mg/kg	30	0.94	2.9	2.7
Arsenic	mg/kg	39	15	86	77
Barium	mg/kg	46,000	420	2,700	1,960
Selenium	mg/kg	1,200	2.6	5.5	5.2
Silver	mg/kg	1,200	2.6	86	60

* The recommended ProUCL software recommended a 95% UCL greater then the maximum concentration. Therefore the maximum value will be used in the risk assessment if warranted.

Table 3. Non-lead metal concentrations in the alley at 6 to 12 inches below the ground surface.

Alley 6-12 inches Lead

The average fine lead concentration in the alley at 6-12 inches bgs is 5060 mg/kg (Table 4). This concentration is greater than 12 times higher than the removal management level for lead and will be carried forward in the risk assessment. However, soils greater than 6 inches bgs are not readily available for exposure to local residents so these values will not be evaluated in the risk assessment.

	Units	RML	Alley 6-12 inches
			Average Concentration
Lead	mg/kg	400	5060

Table 4. Average lead concentrations in the alley at 6-12 inches bgs.

Alley 12-24 inches bgs all non-lead metals

Table 5 below shows the minimum, maximum, and 95% UCL concentrations of metals compared to RMLs from 5 composite samples collected on December 19th, 2013 from 12 to 24 inches below the ground surface (bgs). There are three areas in the alley where concentrations of antimony exceed the RMLs. The 95% UCL for antimony also exceeds the RML. Concentrations of copper exceed the RMLs at two locations in the alley and the

95% UCL also exceeds the RMLs at 12-24 inches bgs in the alley. There is 1 area where the arsenic concentration is above the RML at 12-24 inches bgs in the alley. The 95% UCL for arsenic is above the RML at 12-24 inches bgs in the alley. It is import to note that local residents would not be normally exposed to concentrations of metals below 6 inches in the alley so these concentrations will not be discussed in the risk assessment. However, the concentrations at 12-24 inches bgs may become an issue if any excavation took place in the alley below 12 inches.

	Units	RML	12-24 inches		
			Min	Max	95% UCL
Antimony	mg/kg	94	24	1,200	891
Cadmium	mg/kg	210	3.2	72	57
Chromium	mg/kg	--	17	150	124.
Chromium(III)	mg/kg	350,000	15	129	107
Chromium(VI)	mg/kg	29	2	21	18
Copper	mg/kg	9,400	450	20,000	16,231
Tin	mg/kg	140,000	57	8,200	5,788
Zinc	mg/kg	70,000	980	11,000	9,263
Mercury	mg/kg	30	0.06	9.2	6.36
Arsenic	mg/kg	39	14	93	70
Barium	mg/kg	46,000	300	4,300	3,311
Selenium	mg/kg	1,200	2.3	4.7	4
Silver	mg/kg	1,200	2.3	38	29

Table 5. Non metal concentration in the alley at 12 to 24 inches below the ground surface.

Alley 12-24 inches bgs lead

The average lead concentration in the alley at 12-24 inches bgs is 4900 mg/kg (Table 6). This concentration is greater than 12 times higher than the removal management level for lead and will be carried forward in the risk assessment. However, soils greater than 6 inches bgs are not readily available for exposure to local residents so these values will not be evaluated in the risk assessment.

	Units	RML	Alley 12-24 inches
			Average Concentration
Lead	mg/kg	400	4,900

Table 6. Average lead concentrations in the alley at 12-24 inches bgs.

RAIL SPUR

Rail spur 0-6 inches all non-lead metals

Table 7 below shows the minimum, maximum, and 95% UCL concentrations of metals compared to RMLs from 6 composite samples collected on May 13th, 2013 from 0 to 6

inches below the ground surface (bgs). There is one area in the rail spur area where copper and zinc are both above the RML. However, there are no RML exceedances in the 95% UCL of copper or zinc. There is also one area where the calculated concentration of hexavalent chromium is above the RML. The 95% UCL of chromium is also above the RML. Therefore, only chromium will be carried forward in the risk assessment of the rail spur.

	Units	RML	Rail spur 0-6 inches		
			Min	Max	95% UCL
Antimony	mg/kg	94	4.7	19	17
Cadmium	mg/kg	210	9.3	140	87
Chromium	mg/kg	--	45	900	501
Chromium(III)	mg/kg	350,000	39.0	771	430
Chromium(VI)	mg/kg	29	6.0	129	72
Copper	mg/kg	9,400	770	11,000	8,751
Tin	mg/kg	140,000	70	1,300	950
Zinc	mg/kg	70,000	2,200	78,000	51,825
Mercury	mg/kg	30	0.52	1.2	1.025

Table 7. Non metal concentration in the rail spur at 0 to 6 inches below the ground surface.

Rail spur 0-6 inches lead

The average fine lead concentration in the rail spur area at 0-6 inches bgs is 2286 mg/kg (Table 8). This concentration is greater than 5 times higher than the removal management level for lead and will be carried forward in the risk assessment.

	Units	RML	Alley 0-6 inches
			Average Concentration
Lead	mg/kg	400	2,286

Table 8. Average fine lead concentrations in the rail spur at 0-6 inches bgs.

Railspur 6-24 inches all non-lead metals

Table 9 below shows the minimum, maximum, and 95% UCL concentrations of metals compared to RMLs from 6 composite samples collected on May 13th, 2013 from 6 to 24 inches below the ground surface (bgs). There is one area where hexavalent chromium exceeds the RML. The ProUCL 5.0 software did not give a recommended 95%UCL for hexavalent chromium. Therefore, the maximum concentration of hexavalent chromium would be used in the risk assessment if warranted. However, soils greater than 6 inches bgs are not readily available for exposure to local residents so these values will not be evaluated in the risk assessment.

	Units	RML	Railspur 6-24 inches		
			Min	Max	95% UCL
Antimony	mg/kg	94	4.1	34	32
Cadmium	mg/kg	210	6.1	49	37
Chromium	mg/kg	--	27	2,000	30,426*
Chromium(III)	mg/kg	350,000	23	1,714	24,288*
Chromium(VI)	mg/kg	29	4.0	286	**
Copper	mg/kg	9,400	360	3,700	2,986
Tin	mg/kg	140,000	110	600	476
Zinc	mg/kg	70,000	1100	24,000	16,617
Mercury	mg/kg	30	0.58	1.6	1.2

* The recommended ProUCL software recommended a 95% UCL greater than the maximum concentration. Therefore the maximum value will be used in the risk assessment if warranted.

** No recommended 95% UCL. Therefore the maximum value will be used in the risk assessment if warranted.

Table 9. Non metal concentration in the rail spur at 6 to 24 inches below the ground surface.

Rail spur 6-24 inches bgs lead

The average fine lead concentration in the rail spur area at 0-6 inches bgs is 3140 mg/kg (Table 10). This concentration is greater than 7 times higher than the removal management level for lead and will be carried forward in the risk assessment.

	Units	RML	Alley 6-24 inches
			Average Concentration
Lead	mg/kg	400	3,140

Table 10. Average fine lead concentrations in the rail spur at 6-24 inches bgs.

RISK ASSESSMENT

Non-Lead Metals

Only the surface soils in the alley and rail spur is readily available to the area residents. For this reason risks were only calculated for the non-lead metals with a 95% UCL above the removal management levels in the top six inches of soil in these areas. Appendix A demonstrates how the risk was calculated for both cancer and non-cancer risk in these areas.

Alley

Table 11 shows the risks attributed to the residents to the top six inches of soil in the alley based upon exposure for 9 months out of the year and 50% of their daily incidental soil ingestion coming from these areas. Antimony and chromium(VI) are the only non-lead metals with 95% UCL concentrations above the RMLs in the alley. As can be seen from table 11, there are no non-cancer risks over a hazard index of 1. The calculated excess

lifetime cancer risk from chromium(VI) is within the US EPA acceptable risk range of 1×10^{-4} to 1×10^{-6} .

Alley 0-6 inches Total Health Risk				
Chemical	Non-Cancer Child	Non-Cancer Adolescent	Non-Cancer Adult	Lifetime Cancer Risk
Antimony	2.8E-01	5.9E-04	3.0E-02	NA
Chromium(VI)	1.4E-02	1.2E-04	1.5E-03	2.3E-05
TOTAL RISK =				
	0.3	0.0007	0.03	2.3E-05

Table 11. Total health risk from exposure to non-lead metals in the top 6 inches of soil in the alley.

Rail Spur

Table 12 shows the risks attributed to the residents to the top six inches of soil in the rail spur using the same assumptions listed above. Chromium(VI) is the only non-lead metal with a calculated 95% UCL concentrations above the RMLs in the alley. As can be seen from table 12, there are no non-cancer risks over a hazard index of 1. The calculated excess lifetime cancer risk from chromium(VI) is within the US EPA acceptable risk range of 1×10^{-4} to 1×10^{-6} .

Rail Spur 0-6 inches Total Health Risk				
Chemical	Non-Cancer Child	Non-Cancer Adolescent	Non-Cancer Adult	Lifetime Cancer Risk
Chromium(VI)	3.1E-03	5.0E-04	3.5E-04	5.2E-06
TOTAL RISK =				
	0.003	0.0005	0.0003	5.2E-06

Table 12. Total health risk from exposure to non-lead metals in the top 6 inches of soil in the rail spur.

LEAD

The US EPA recommends that residential soils do not exceed 400 mg/kg of lead. It also recommends that commercial/industrial property soils do not exceed 800 mg/kg of lead. These concentrations are based upon protecting children from exceeding the Center for Disease Control and Prevention (CDC) recommended blood lead level of 10 µg/dl in blood. Recently, CDC changed their guidance to recommend that the blood lead levels of children do not exceed blood lead levels of 5 µg/dl. As discussed previously, the fine lead concentrations was used for this assessment since it are more readily available for human exposure. Lead concentrations from the top six inches of soil were averaged for the alley, the rail spur, and each individual residential location and compared to the RML of 400 mg/kg.

Alley

The alley has an average fine particle lead concentration of 2,491 mg/kg. This is 6 times greater than the lead RML. This concentration was input into the IEUBK model using standard default parameters. The IEUBK model predicted that the average blood lead level for children being exposed to the alley would be 17.5µg/dl. The ALM model

predicted that 100% probability that fetal blood of pregnant woman exposed to the alley for 9 months out of the year would exceed 5µg/dl (table 13). It is important to note that the concentrations of fine lead in the alley at depths greater than 6 inches are well over the concentration at 0-6 inches below the surface, so the risk is greater at 6-24 inches where the average concentration exceed 4900 mg/kg.

Rail Spur

The rail spur has an average fine particle lead concentration of 2,491 mg/kg. This is 6 times greater than the lead RML. This concentration was input into the IEUBK model using standard default parameters. The IEUBK model predicted that the average blood lead level for children being exposed to the alley would be 16.5µg/dl. The ALM model predicted that 100% probability that fetal blood of pregnant woman exposed to the alley for 9 months out of the year would exceed 5µg/dl (table 13). The average concentrations of fine lead in the rail spur at 6 to 24 below the surface is of 3,140 mg/kg. Therefore, the risk is greater from exposure to soils greater than 6 inches below the surface.

	Recommended Child Blood Lead Level ug/dl	IEUBK Predicted Blood Lead Level of Exposed Child ug/dl	ALM Predicted Probability of Fetal Blood Lead Exceeding 5 ug/dl Through Exposed Pregnant Mother.
Alley	5	17.5	100%
Rail Spur	5	16.5	100%

Table 13. Predicted lead risk to children from exposure to the Alley and Rail Spur

CONCLUSIONS

Alley

The alley has an average fine lead concentration at the surface of approximately 6.5 times higher than the protective removal management level and greater than 10 times the RML and a depth of 6 to 24 inches of soil. There are also a few areas in the top 6 inches of soil in alley where antimony exceeds the removal management level. The calculated concentration of chromium(VI) also exceeds the RML at a number of locations in the alley. Due to these reasons the current concentrations in the alley are at an unacceptable risk level to the residents in the neighborhood surrounding the H. Kramer Smelter.

Rail Spur

The rail spur has an average fine lead concentration at the ground surface of approximately 6 times higher than the protective removal management level and greater than 7 times the RML and a depth of 6 to 24 inches of soil. There are also a few areas of the rail spur where the calculated concentration of chromium (VI) exceeds the RMLs. Due to these reasons the current concentrations in the rail spur are at an unacceptable risk level to the residents in the neighborhood surrounding the H. Kramer Smelter.

It is important to note the role that background concentrations of the contaminants of concern play in the cleanup in these areas. Background refers to substances or locations

that are not influenced by the releases from a site, and are usually described as naturally occurring or anthropogenic (man-made). As discussed in "Role of Background in the CERCLA Cleanup Program" OSWER 9285.6-07P, US EPA cannot clean up contaminants below concentrations which are determined to be the background concentration, even if the concentration of the contaminant is above a health based screening criteria.

REFERENCES

- US EPA 1989. Risk Assessment Guidance for Superfund. Volume I. Human Health Evaluation Manual (Part A)
- US EPA 1997. Exposure Factors Handbook.
- US EPA 2002. Role of Background in the CERCLA Cleanup Program. OSWER 9285.6-07P
- US EPA 2003. Superfund Lead-Contaminated Residential Sites Handbook.
- US EPA 2003. Assessing Intermittent or Variable Exposures at Lead Sites.
- US EPA 2004. Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment)
- US EPA 2009. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment)
- US EPA 2011 Exposure Factors Handbook: 2011 Edition
- Weston 2014. Pilsen Soil Site: Railroad/Alley Site Assessment Report

Appendix A

The equations used to determine health risk for local residents near the Pilsen Site are described below along with examples as to how these equations were used.

ABS_d = Absorbance factor (0.1 – RAGS E)

ABS_{gi} = Fraction of contaminant absorbed via GI tract (0.15 for Antimony; 0.025 for chromium – Regional Screening Level Tables)

AF_c = Soil to Skin Adherence Factor for Child (dry soil = 0.04 mg/cm²)

AF_a = Soil to Skin Adherence Factor for Adult or Adolescent (dry soil = 0.011 mg/cm²)

AT = Averaging time (cancer = 365 days/year x 70 years = 25550 days)
(non-cancer child = 365 days/year x 6 years = 2190 days)
(non-cancer adolescent = 365 days/year x 12 years = 3650 days)
(non-cancer adult = 365 days/year x 10 years = 3650 days)

BW_c = Body Weight for Child (15kg)

BW_{ad} = Body Weight for Child (48kg)

BW_a = Body Weight for Adult (70kg)

CF = Conversion factor (1×10^{-6} kg/1mg)

$Conc$ = Measured Concentration (mg/kg)

DA_{event} = Absorbed Dose per Event (mg/cm²-event)

ED_c = Exposure Duration Child non-cancer (6 years)

ED_{ad} = Exposure Duration adolescent non-cancer (12 years)

ED_a = Exposure Duration Adult (10 years for cancer; 30 years for non-cancer)

EF = Exposure Frequency (1 hour/day)

EV = Exposure frequency (365 days a week x 9months/12 months = 274 days)

HQ = Hazard Quotient (sum of all Hazard Indexes = should be less than 1)

Ing_c = Soil Ingestion Rate for Child (50% x 200mg/day = 100mg/day)

Ing_a = Soil Ingestion Rate for Adult (50% x 100mg/day = 50mg/day)

IUR = Inhalation Unit Risk (Chemical Specific)

Rfd_o = Oral reference dose from IRIS or applicable tables (mg/kg-day)

SA_{c(warm)} = Exposed Skin Surface for Child “warmer” months (hands, forearms, lower legs, head, and face exposed = 2640 cm²)

SA_{c(win)} = Exposed Skin Surface for Child winter (hands, head and face exposed = 1320 cm²)

SA_{ad(warm)} = Exposed Skin Surface for Adolescent “warmer” months (hands, forearms, lower legs, head, and face exposed = 4788 cm²)

SA_{ad(win)} = Exposed Skin Surface for Adolescent winter (hands, head and face exposed = 2388 cm²)

SA_{a(warm)} = Exposed Skin Surface for Adult “warmer months (hands, forearms, lower legs, head, and face exposed = 7200 cm²)

SA_{a(win)} = Exposed Skin Surface for Adult winter (hands, head and face exposed = 3600 cm²)

Sf_o = Cancer Slope factor Chemical Specific based upon Regional Screening Level Tables

Ingestion of Soil

Daily Ingestion Rate for Child = Conc x Ing_c x CF x EV x EF x ED x ABS_{gi} / (BW_c x AT)

Daily Ingestion Rate for Adult = Conc x Ing_a x CF x EV x EF x ED x ABS_{gi} / (BW_a x AT)

Dermal Contact with Soil

Non-Cancer Risk

DA_{event} = conc x CF x AF x ABS_d

Daily Average Dose = DA_{event} x EF x ED x EV x SA / BW x AT

HI = Daily Average Dose / Rfd_o

INHALATION RISK

Average Daily Dose = IUR x EF x ED x (1/PEF) / AT

HI non-cancer = Daily Average Dose/Rfc x CFi

Excess Lifetime Cancer Risk = Daily Average Dose x IUR

Total Risk

Cancer Risk = Daily Average Dose x SF_o

Total Cancer Risk = Σ Cancer Risk

Total Non-Cancer Risk (HQ) = Σ HI

Example

The 95% UCL concentration of hexavalent chromium in the top 6 inches of soil on the alley is 320. Health risks for the residents in the area of the Pilsen site from these concentrations are determined below.

Non-Cancer –child

Ingestion

$$(320 \text{ mg chromium VI/kg} \times 100\text{mg/day} \times 1 \times 10^{-6} \text{ kg/mg} \times 274 \text{ days} \times 6 \text{ years} \times 0.025) / (15 \text{ kg} \times 2190 \text{ days})$$

This results in a daily dose of 9.0×10^{-6} chromium(VI) mg/kg-day for a child.

This value is then divided by Rfd_o to determine total non-cancer risk

9.0×10^{-6} chromium(VI) mg/kg-day / 3×10^{-3} chromium(VI) mg/kg-day = a hazard index of **3×10^{-3} by soil ingestion**

Dermal Contact

$$\text{The DA}_{\text{event}} = 320 \text{ mg/kg} \times 1 \times 10^{-6} \text{ kg/mg} \times 0.04 \text{ mg/cm}^2 \times 0.1 = 1.28 \times 10^{-7} \text{ mg/cm}^2\text{-event}$$

Therefore;

Daily dose during the warmer months

$$= (1.28 \times 10^{-7} \text{ mg/cm}^2\text{-event} \times 1 \times 91 \text{ days/year} \times 6 \text{ years} \times 2640 \text{ cm}^2) / (15 \text{ kg} \times 2190 \text{ days}) \\ = 5.6 \times 10^{-6} \text{ mg/kg-day}$$

Daily dose during the cooler months

$$= (1.28 \times 10^{-7} \text{ mg/cm}^2\text{-event} \times 1 \times 183 \text{ days/year} \times 6 \text{ years} \times 1320 \text{ cm}^2) / (15 \text{ kg} \times 2190 \text{ days}) \\ = 5.7 \times 10^{-6} \text{ mg/kg-day}$$

The hazard index is calculated by dividing both daily doses for cooler and winter months by the reference dose as shown in the calculation below.

$$1/(1/(5.6 \times 10^{-6} \text{ mg/kg-day}/3 \times 10^{-3}) + (1/(5.7 \times 10^{-6} \text{ mg/kg-day}/3 \times 10^{-3}))) = 9 \times 10^{-4}$$

This results in a total Dermal Hazard Index for children of **9×10^{-4}** .

Inhalation

$$320 \text{ mg/kg} \times 274 \text{ days} \times 6 \text{ years} \times (1/1.36 \times 10^9) / 2190 \text{ days} = 1.8 \times 10^{-7} \text{ mg/kg-day}$$

$$\text{HI} = 1.8 \times 10^{-7} \text{ mg/kg-day} / 1 \times 10^{-4} = \mathbf{2 \times 10^{-6}}$$

The total non-cancer hazard index for a child for chromium is calculated by adding the HI for each exposure pathway.

$$\text{Total HI} = 3 \times 10^{-3} + 9 \times 10^{-4} + 2 \times 10^{-6} = \mathbf{3 \times 10^{-3}}$$

Non-Cancer –Adolescent

Ingestion

$$(320 \text{ mg chromium VI/kg} \times 50 \text{ mg/day} \times 1 \times 10^{-6} \text{ kg/mg} \times 274 \text{ days} \times 12 \text{ years} \times 0.025) / (48 \text{ kg} \times 4380 \text{ days})$$

This results in a daily dose of 3.4×10^{-11} chromium(VI) mg/kg-day for a child.

This value is then divided by Rfd_o to determine total non-cancer risk

$$3.4 \times 10^{-11} \text{ chromium(VI) mg/kg-day} / 3 \times 10^{-3} \text{ chromium(VI) mg/kg-day} = \text{a hazard index of } \mathbf{1 \times 10^{-8} \text{ by soil ingestion}}$$

Dermal Contact

$$\text{The DA}_{\text{event}} = 320 \text{ mg/kg} \times 1 \times 10^{-6} \text{ kg/mg} \times 0.11 \text{ mg/cm}^2 \times 0.1 = 3.5 \times 10^{-8} \text{ mg/cm}^2\text{-event}$$

Therefore;

Daily dose during the warmer months

$$= (3.5 \times 10^{-8} \text{ mg/cm}^2\text{-event} \times 1 \times 91 \text{ days/year} \times 12 \text{ years} \times 4788 \text{ cm}^2) / (48 \text{ kg} \times 4380 \text{ days}) \\ = 1.8 \times 10^{-6} \text{ mg/kg-day}$$

Daily dose during the cooler months

$$= (3.5 \times 10^{-8} \text{ mg/cm}^2\text{-event} \times 1 \times 183 \text{ days/year} \times 12 \text{ years} \times 2388 \text{ cm}^2) / (48 \text{ kg} \times 4380 \text{ days}) \\ = 4.4 \times 10^{-7} \text{ mg/kg-day}$$

The hazard index is calculated by dividing both daily doses for cooler and winter months by the reference dose as shown in the calculation below.

$$1/(1/(4.4 \times 10^{-7} \text{ mg/kg-day}/3 \times 10^{-3}) + (1/(1.0 \times 10^{-7} \text{ mg/kg-day}/3 \times 10^{-3}))) = 1 \times 10^{-4}$$

This results in a total Dermal Hazard Index for children of **1x10⁻⁴**.

Inhalation

$$320 \text{ mg/kg} \times 274 \text{ days} \times 12 \text{ years} \times (1/1.36 \times 10^9) / 4380 \text{ days} = 1.8 \times 10^{-8} \text{ mg/kg-day}$$

$$\text{HI} = 1.8 \times 10^{-8} \text{ mg/kg-day} / 1 \times 10^{-4} = \mathbf{2 \times 10^{-6}}$$

The total non-cancer hazard index for a child for chromium is calculated by adding the HI for each exposure pathway.

$$\text{HI} = 1 \times 10^{-8} + 1 \times 10^{-4} + 2 \times 10^{-6} = \mathbf{1 \times 10^{-4}}$$

Non-cancer Adult

Ingestion

$$(320 \text{ mg chromium VI/kg} \times 50 \text{ mg/day} \times 1 \times 10^{-6} \text{ kg/mg} \times 274 \text{ days} \times 10 \text{ years} \times 0.025) / (70 \text{ kg} \times 3650 \text{ days})$$

This results in a daily dose of 4.3×10^{-6} chromium(VI) mg/kg-day for a child.

This value is then divided by Rfd_o to determine total non-cancer risk

$$4.3 \times 10^{-6} \text{ chromium(VI) mg/kg-day} / 3 \times 10^{-3} \text{ chromium(VI) mg/kg-day} = \text{a hazard index of } \mathbf{1 \times 10^{-3} \text{ by soil ingestion}}$$

Dermal Contact

$$\text{The DA}_{\text{event}} = 320 \text{ mg/kg} \times 1 \times 10^{-6} \text{ kg/mg} \times 0.11 \text{ mg/cm}^2 \times 0.1 = 3.5 \times 10^{-8} \text{ mg/cm}^2\text{-event}$$

Therefore;

Daily dose during the warmer months

$$= (3.5 \times 10^{-8} \text{ mg/cm}^2\text{-event} \times 1 \times 91 \text{ days/year} \times 10 \text{ years} \times 7200 \text{ cm}^2) / (70 \text{ kg} \times 3650 \text{ days}) \\ = 9.0 \times 10^{-7} \text{ mg/kg-day}$$

Daily dose during the cooler months

$$= (3.5 \times 10^{-8} \text{ mg/cm}^2\text{-event} \times 1 \times 183 \text{ days/year} \times 10 \text{ years} \times 3600 \text{ cm}^2) / (70 \text{ kg} \times 3650 \text{ days}) \\ = 4.5 \times 10^{-7} \text{ mg/kg-day}$$

The hazard index is calculated by dividing both daily doses for cooler and winter months by the reference dose as shown in the calculation below.

$$1/(1/(9.0 \times 10^{-7} \text{ mg/kg-day}/3 \times 10^{-3}) + (1/(4.5 \times 10^{-7} \text{ mg/kg-day}/3 \times 10^{-3}))) = 1 \times 10^{-4}$$

This results in a total Dermal Hazard Index for children of **1×10^{-4}** .

Inhalation

$$320 \text{ mg/kg} \times 274 \text{ days} \times 10 \text{ years} \times (1/1.36 \times 10^9) / 3650 \text{ days} = 1.4 \times 10^{-6} \text{ mg/kg-day}$$

$$\text{HI} = 1.4 \times 10^{-6} \text{ mg/kg-day} / 1 \times 10^{-4} = \mathbf{1 \times 10^{-5}}$$

The total non-cancer hazard index for a child for chromium is calculated by adding the HI for each exposure pathway.

$$\text{HI} = 1 \times 10^{-3} + 1 \times 10^{-4} + 1 \times 10^{-5} = \mathbf{1 \times 10^{-3}}$$

Cancer -child

Cancer Risk is assessed by the same method except the averaging time of 25550 is used to determine cancer risk over a lifetime.

Ingestion

$$(320 \text{ mg chromium VI/kg} \times 100 \text{ mg/day} \times 1 \times 10^{-6} \text{ kg/mg} \times 274 \text{ days} \times 6 \text{ years} \times 0.025) / (15 \text{ kg} \times 25550 \text{ days})$$

This results in a daily dose of 3.4×10^{-6} chromium(VI) mg/kg-day for a child.

This value is then multiplied by the cancer slope factor to determine total non-cancer risk

3.4×10^{-6} chromium(VI) mg/kg-day $\times 5 \times 10^{-1}$ chromium(VI) mg/kg-day = an excess lifetime cancer risk (ELCR) of **1.7×10^{-6} by soil ingestion**

Dermal Contact

$$\text{The DA}_{\text{event}} = 320 \text{ mg/kg} \times 1 \times 10^{-6} \text{ kg/lmg} \times 0.04 \text{ mg/cm}^2 \times 0.1 = 1.28 \times 10^{-7} \text{ mg/cm}^2\text{-event}$$

Therefore;

Daily dose during the warmer months

$$= (1.28 \times 10^{-7} \text{ mg/cm}^2\text{-event} \times 1 \times 91 \text{ days/year} \times 6 \text{ years} \times 2640 \text{ cm}^2) / (15 \text{ kg} \times 25550 \text{ days}) \\ = 4.8 \times 10^{-7} \text{ mg/kg-day}$$

Daily dose during the cooler months

$$= (1.28 \times 10^{-7} \text{ mg/cm}^2\text{-event} \times 1 \times 183 \text{ days/year} \times 6 \text{ years} \times 1320 \text{ cm}^2) / (15 \text{ kg} \times 25550 \text{ days})$$

$$= 4.8 \times 10^{-7} \text{ mg/kg-day}$$

The ELCR is calculated by multiplying both daily doses for cooler and winter months by the cancer slope factor as shown in the calculation below.

$$1/(1/(4.8 \times 10^{-7} \text{ mg/kg-day} \times 5 \times 10^{-1}) + (1/(4.8 \times 10^{-7} \text{ mg/kg-day} \times 5 \times 10^{-1}))) = 1 \times 10^{-7}$$

This results in a total Dermal Hazard Index for children of **1x10⁻⁷**.

Inhalation

$$320 \text{ mg/kg} \times 274 \text{ days} \times 6 \text{ years} \times (1/1.36 \times 10^9) / 25550 \text{ days} = 1.5 \times 10^{-8} \text{ mg/kg-day}$$

$$\text{ELCR} = 1.5 \times 10^{-8} \text{ mg/kg-day} \times 8.4 \times 10^{-2} \text{ 1000ug/mg} = \mathbf{1.3 \times 10^{-6}}$$

Cancer –Adolescent

Ingestion

$$(320 \text{ mg chromium VI/kg} \times 50 \text{ mg/day} \times 1 \times 10^{-6} \text{ kg/mg} \times 274 \text{ days} \times 12 \text{ years} \times 0.025) / (48 \text{ kg} \times 25550 \text{ days})$$

This results in a daily dose of 9.8×10^{-13} chromium(VI) mg/kg-day for a child.

This value is then multiplied by the cancer slope factor to determine the ELCR

$$9.8 \times 10^{-13} \text{ chromium(VI) mg/kg-day} \times 5 \times 10^{-1} \text{ chromium(VI) mg/kg-day} = \text{a ELCR of } \mathbf{4.9 \times 10^{-13} \text{ by soil ingestion}}$$

Dermal Contact

$$\text{The DA}_{\text{event}} = 320 \text{ mg/kg} \times 1 \times 10^{-6} \text{ kg/mg} \times 0.11 \text{ mg/cm}^2 \times 0.1 = 3.5 \times 10^{-8} \text{ mg/cm}^2\text{-event}$$

Therefore;

Daily dose during the warmer months

$$= (3.5 \times 10^{-8} \text{ mg/cm}^2\text{-event} \times 1 \times 91 \text{ days/year} \times 12 \text{ years} \times 4788 \text{ cm}^2) / (48 \text{ kg} \times 25550 \text{ days})$$

$$= 1.5 \times 10^{-7} \text{ mg/kg-day}$$

Daily dose during the cooler months

$$= (3.5 \times 10^{-8} \text{ mg/cm}^2\text{-event} \times 1 \times 183 \text{ days/year} \times 12 \text{ years} \times 2388 \text{ cm}^2) / (48 \text{ kg} \times 25550 \text{ days})$$

$$= 1.5 \times 10^{-7} \text{ mg/kg-day}$$

The ELCR is calculated by multiplying both daily doses for cooler and winter months by the cancer slope factor as shown in the calculation below.

$$1/(1/(1.5 \times 10^{-7} \text{ mg/kg-day} \times 5 \times 10^{-1}) + (1/(1.5 \times 10^{-7} \text{ mg/kg-day} \times 5 \times 10^{-1}))) = 3.8 \times 10^{-8}$$

This results in a Dermal ELCR for children of **3.8×10^{-8}** .

Inhalation

$$320 \text{ mg/kg} \times 274 \text{ days} \times 12 \text{ years} \times (1/1.36 \times 10^9) / 25550 \text{ days} = 3.0 \times 10^{-8} \text{ mg/kg-day}$$

$$\text{ELCR} = 1.8 \times 10^{-8} \text{ mg/kg-day} \times 5 \times 10^{-1} \text{ } 1000 \text{ ug/mg} = \mathbf{2.5 \times 10^{-6}}$$

Cancer Adult

Ingestion

$$(320 \text{ mg chromium VI/kg} \times 50 \text{ mg/day} \times 1 \times 10^{-6} \text{ kg/mg} \times 274 \text{ days} \times 10 \text{ years} \times 0.025) / (70 \text{ kg} \times 25550 \text{ days})$$

This results in a daily dose of 6.1×10^{-7} chromium(VI) mg/kg-day for a child.

This value is then multiplied by the cancer slope factor to determine cancer risk

$$6.1 \times 10^{-7} \text{ chromium(VI) mg/kg-day} \times 5 \times 10^{-1} \text{ chromium(VI) mg/kg-day} = \text{an ELCR of } \mathbf{3.1 \times 10^{-7} \text{ by soil ingestion}}$$

Dermal Contact

$$\text{The DA}_{\text{event}} = 320 \text{ mg/kg} \times 1 \times 10^{-6} \text{ kg/mg} \times 0.11 \text{ mg/cm}^2 \times 0.1 = 3.5 \times 10^{-8} \text{ mg/cm}^2\text{-event}$$

Therefore;

Daily dose during the warmer months

$$= (3.5 \times 10^{-8} \text{ mg/cm}^2\text{-event} \times 1 \times 91 \text{ days/year} \times 10 \text{ years} \times 7200 \text{ cm}^2) / (70 \text{ kg} \times 25550 \text{ days})$$

$$= 1.3 \times 10^{-7} \text{ mg/kg-day}$$

Daily dose during the cooler months

$$= (3.5 \times 10^{-8} \text{ mg/cm}^2\text{-event} \times 1 \times 183 \text{ days/year} \times 10 \text{ years} \times 3600 \text{ cm}^2) / (70 \text{ kg} \times 25550 \text{ days})$$

$$= 1.3 \times 10^{-7} \text{ mg/kg-day}$$

The ELCR is calculated by multiplying both daily doses for cooler and winter months by the cancer slope factor as shown in the calculation below.

$$1/(1/(1.3 \times 10^{-7} \text{ mg/kg-day} \times 5 \times 10^{-1}) + (1/(1.3 \times 10^{-7} \text{ mg/kg-day} \times 5 \times 10^{-1}))) = 7.4 \times 10^{-16}$$

This results in a Dermal ELCR for adults of **7.4×10^{-16}** .

Inhalation

$$320 \text{ mg/kg} \times 274 \text{ days} \times 10 \text{ years} \times (1/1.36 \times 10^9) / 25550 \text{ days} = 2.0 \times 10^{-7} \text{ mg/kg-day}$$

$$\text{HI} = 2.0 \times 10^{-7} \text{ mg/kg-day} \times 8.4 \times 10^{-2} \times 1000 \text{ ug/mg} = \mathbf{1.7 \times 10^{-5}}$$

The total non-cancer hazard index for a child for chromium is calculated by adding the HI for each exposure pathway.

$$\text{HI} = 1 \times 10^{-3} + 1 \times 10^{-4} + 1 \times 10^{-5} = \mathbf{1 \times 10^{-3}}$$